THE UNIVERSITY OF ALBERTA

SUMMATION IN SECOND-ORDER CONDITIONING

by

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Dedication

Thanks to _Rattus_.

Here's to _Oncorhynchus_.

Abstract

Using rats in a conditioned suppression paradigm, an experiment investigated the hypothesis that the second-order reinforcing power of a conditioned stimulus (CS1) is a function of its ability to elicit conditioned responding during second-order trials. Conditioned responding to CS1 was affected in three groups by varying the manner of CS1 presentations during first- and second-order trials. For one group element CS1s were presented during first-order conditioning and compound CS1s consisting of the elements were presented during second-order conditioning. This constituted a summation procedure. For two other groups CS1s did not change from first- to second-order conditioning. One of these groups received element CS1s, the other received compound CS1s. It was predicted that the group receiving the summation procedure would show greater conditioned responding to CS1, resulting in greater second-order conditioned responding than the groups receiving no change in CS1. In addition to these three groups, two others necessary to demonstrate second-order conditioning were included. Results indicated substantial second-order conditioning for the three second-order groups compared to the two second-order controls. As predicted, the summation group showed greater second-order conditioned responding than the group receiving element CS1s in both first- and second-order stages. However, the prediction that the summation group would show greater second-order conditioned

responding than the group receiving the compound in both first- and second-order stages was not supported. Several factors which may have been responsible for this result were considered.

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I. Introduction

The study of Pavlovian conditioning may be viewed as an inquiry into the organism's sensitivity to relations among events (Rescorla & Holland, 1975). In a typical first-order conditioning procedure, a relatively neutral event known as a conditioned stimulus (CS1), is paired with a more salient event known as an unconditioned stimulus (US), until CS1 comes to control a conditioned response (CR) (Rescorla, 1975). The US is said to "reinforce" conditioned responding, and so is referred to as a Pavlovian reinforcer. In second-order conditioning an additional manipulation is performed after the first-order CR is established: some other stimulus (CS2) is paired with CS1 in the absence of the US. Thus, in second-order conditioning the CS1 plays the role of Pavlovian reinforcer. The ability of CS2 to elicit a CR, as a joint result of first- and second-order procedures, is taken as evidence for second-order conditioning (Rizley & Rescorla, 1972).

Among the properties of a stimulus that may constitute its capacity to serve as a Pavlovian reinforcer, the ability to elicit a response has generally received the most attention. With regard to first-order conditioning, Pavlov (1927, pp.31-32) suggested that the US must reliably elicit an unconditioned response (UR) in order to be an effective reinforcer. Whether Pavlov meant this as a practical guideline or as a theoretical formulation, the notion has

been perpetuated in the learning literature. For example, Kling (1971) states, "The most important property of the unconditioned stimulus is that it elicit the UR with a very high degree of reliability"(p.557). Mackintosh (1974, pp.71-124) has examined evidence related to the necessity of the UR to establish conditioning. Although his analysis implied that an overt UR is not necessary to establish conditioning, he noted that the Pavlovian assumption may remain current by conceiving of the UR as a centralized response, such as a motivational state. There has been less discussion as to the nature of Pavlovian second-order reinforcement, but here too the response elicited by the Pavlovian reinforcer, CS1, has received attention. Rescorla (1977) has proposed, "The repeated pairing of the second-order CS with a strong response is <u>the</u> important condition for second-order conditioning" (italics in original, p.160). Serving as the working hypothesis for the present investigation, an extension of Rescorla's formulation proposes that any operation altering the magnitude of the CR to CS1 should affect the amount of second-order conditioning that CS1 can support.

Conditioned responding to CS1 can be affected by several methods. There follows a brief review of some of these methods and how they have been used to affect the CR to CS1 during second-order conditioning.

In first-order conditioning of conditioned suppression in rats, the strength of the CR to a CS1 is a positive

function of the intensity of the US (Annau & Kamin, 1961; Kamin & Brimer, 1963). This effect of US intensity upon conditioned responding to CS1 has been shown, by Davenport (1966) and Zimmer-Hart (note 1), to be reflected in the amount of second-order conditioned responding that CS1 can support. These researchers have found the strength of second-order conditioned responding to be a function of the intensity of the US used to condition CS1.

The CR to CS1 can also be affected by altering the physical characteristics of CS1 after first-order conditioning is completed. Heinemann & Chase (1970) found that increasing the intensity of an auditory CS1 after first-order conditioning intensified the resulting CR. Zimmer-Hart (note 1) used this method of varying the CR to CS1 and demonstrated that such increased responding to CS1 during second-order trials supported increased second-order conditioned responding.

Another way of altering the CR to CS1 has been to employ a summation procedure. This procedure involves a comparison between two methods of presenting CS1 after first-order conditioning. First-order conditioning is given with two individual CS1 elements, then the elements are presented either in compound or in isolation. A typical result is that the compound CS1 elicits greater responding than do either of its components presented alone (Pavlov, 1927, p.27). This phenomenon occurs reliably in the conditioned suppression paradigm (Miller, 1969; Reberg &

Black, 1969; VanHouten, O'Leary & Weiss, 1970; Weiss & Emurian, 1970). Further, summation enhances the CR over and above simply increasing the effective intensity of the elements via their compounding (Miller,1969; Reberg & Black, 1969). Holland (1977) employed the summation procedure to alter the CR-eliciting potency of CS1 during second-order conditioning. Two CS1s were individually paired with food USs during first-order conditioning. Subsequent second-order conditioning trials used CS1s of two types: either the individual element CS1s, or both CS1s in a simultaneous compound. The compound CS1 maintained greater second-order conditioned responding than did either individual element. It would be desirable to extend the generality of the effect to include aversive conditioning.

A final method of altering the strength of the CR to CS1 has been illustrated by Wagner (1971, pp. 201-203). Wagner assessed conditioned suppression to a compound CS1 in independent groups which had previously received conditioning with either the compound itself, or its elements. Two groups of rats received 80 conditioning trials consisting of compound or element CS1 presentations reinforced by shock USs. The element group (A+B+) received 40 reinforced tones and 40 reinforced lights, while the compound group (AB+) received 80 reinforced tone-light compounds. Both groups then received test trials consisting of nonreinforced presentations of the compound. On these test trials group A+B+ showed greater conditioned

suppression than group AB+. Thus, element training led to greater conditioned suppression to the compound than did training with the compound itself. This suggests that if second-order conditioning were given with a compound CS1, previous conditioning of that CS1's elements would support greater second-order conditioning than would previous conditioning of the compound itself. This hypothesis has not yet been tested.

The present study had three major purposes:

1. To provide an additional convincing demonstration of second-order conditioning, incorporating the necessary control groups employed by Rizley and Rescorla (1972). These controls insured that experimental observations were made within the context of second-order conditioning.
2. To attempt to extend Holland's (1977) finding that compounding of individually trained CS1s during second-order conditioning resulted in greater second-order conditioned responding than did either element alone, to an aversive conditioning situation.
3. To assess the strength of second-order conditioned responding as a function of Wagner's (1971) first-order conditioning procedures. The specific prediction was that when second-order conditioning employed a compound CS1, previous first-order conditioning of the elements of that compound would lead to greater second-order conditioned responding than would previous training with

the compound itself.

II. Method

A. Design

The experimental design is outlined in Table I. Since second-order conditioning is a joint result of CS1-US pairings and CS2-CS1 pairings, a firm demonstration of second-order conditioning requires two control groups (Rizley & Rescorla, 1972). One control allows assessment of the possiblity that CS1's ability to reinforce suppression to CS2 during second-order conditioning has been acquired during first-order conditioning. This control, because it assesses the unconditioned reinforcing powers of CS1, is referred to as the "reinforcement control", and so was denoted as Group R. The second control allows assessment of the possiblity that suppression to CS2 merely reflects stimulus generalization from CS1. This control for generalization was denoted as Group G. The reinforcement and generalization controls have typically been accomplished by presenting experimental events in an explicitly unpaired fashion (Holland & Rescorla, 1975; Rizley & Rescorla, 1972). In the present study, Group R received explicitly unpaired CS1 and US presentations during first-order conditioning trials, and Group G received explicitly unpaired CS2 and CS1 presentations during second-order conditioning trials.

Two additional groups were employed in order to extend Holland's summation procedure to the aversive conditioning

Groups	Phase of Experiment						
	Pretest CS1s (2 days)	First-order Conditioning (4 days)	Pretest CS2 (1 day)	Second-order Conditioning (3 days)	Extinction: compound (5 days)	& element (3 days)	Test CS2 (1 day)
I-C	2(T) & 2(L)	2(L→sh) & 2(T→sh)	4(N)	4(N→TL)	6(TL)	3(T) & 3(L)	4(N)
I-I	2(T) & 2(L)	2(L→sh) & 2(T→sh)	4(N)	4(N→T) or 4(N→L)	6(TL)	3(T) & 3(L)	4(N)
C-C	2(T) & 2(L)	4(TL→sh)	4(N)	4(N→TL)	6(TL)	3(T) & 3(L)	4(N)
G	2(T) & 2(L)	4(TL→sh)	4(N)	4(N) & 4(TL)	6(TL)	3(T) & 3(L)	4(N)
R	2(T) & 2(L)	4(TL) & 4(sh)	4(N)	4(N→TL)	6(TL)	3(T) & 3(L)	4(N)

Table I.

Experimental design and stimulus exposures for each group.
Stimulus symbols: T=tone, L=light, N=white noise, sh=shock.

situation. Both groups were identically trained during first-order conditioning, receiving pairings of individual CS1 elements (seperate tones and lights) with shock. During second-order conditioning one group received pairings of CS2 (white noise) with a compound (tone-light) consisting of the previously conditioned CS1 elements. Because this group received individual CS1s in first-order conditioning and compound CS1s in second-order conditioning, it was denoted as Group I-C. The second group received individual CS1 elements in both first-order conditioning and second-order conditioning, and was denoted as Group I-I. Half of the subjects in Group I-I received tone CS1s during second-order conditioning, while the remainder of this group received light CS1s.

The extension of Wagner's (1971) procedure to the present study demanded additions to the basic second-order conditioning design. Second-order conditioning supported by a compound CS1 was to be compared between a group (I-C) conditioned with the individual elements of that compound during first-order conditioning, and a group (C-C) conditioned with the compound itself. Group I-C was expected to show more conditioned suppression to the compound CS1 than C-C. Because of this greater CR-eliciting power, greater second-order conditioned responding to CS2 was expected to be evinced by I-C than by C-C. However, since CS1 was expected to elicit greater conditioned responding in Group I-C than in Group C-C, it might also have been

expected to have more potential for stimulus generalization to CS2 in Group I-C than in Group C-C. In other words, it might be ambiguous whether Group I-C's greater responding to CS2 during second-order conditioning reflected greater second-order conditioning or greater stimulus generalization from CS1. It was therefore desirable to devise a method to assess responding to CS2 in the absence of such possible generalization. After second-order conditioning, the CS1 compound and elements were extinguished by repeated nonreinforced presentations to reduce this source of generalization. Rizley and Rescorla (1972) and Holland and Rescorla (1975) found that extinction of CS1 had little effect upon the maintainance of previously established second-order responding. Thus, extinguishing CS1 after second-order conditioning should have removed this possible source of generalization, leaving second-order conditioned responding to CS2 intact. It should be noted that differential generalization was simply an anticipated possiblity. One way to assess this generalization was to present the noise CS2 after first-order conditioning, but before second-order conditioning. If differential generalization was a factor, it should have been detected in this noise pretest. Since no generalization was detected, the data of primary interest were obtained during second-order conditioning.

B. Subjects and Apparatus

The subjects were 40 male SpragueDawley rats, obtained from Holtzman Co., Madison, Wisconsin. At the start of the experiment the subjects were 90 to 95 days old. Subjects were maintained on a deprivation schedule consisting of 5 minutes access to water in the home cages at the end of each daily experimental session. Food was provided ad libitum.

The apparatus consisted of eight identical conditioning chambers 23.5 cm long, 21 cm wide, and 19.5 cm high. The front and back walls and top were clear plexiglass. The floor was made of stainless steel bars .4 cm in diameter spaced 1 cm apart, and set parallel to the front wall. A lever was centered on the front wall 5.5 cm from the floor. On the same wall, a water well 3 cm in diameter was situated 4 cm from the floor and 3 cm to the right of the lever. Each conditioning chamber was enclosed in a Coulbourne Instruments sound attenuation shell equipped with a ventilation fan.

Mounted on the top of each chamber were a 2.9 khz Mallory sonalert, a 24 V bulb, and a loudspeaker. The intensity of the sonalert was adjusted to .7dB above the background noise of the ventilation fan. The intensity of the white noise was 1.6 dB above the background noise of the ventilation fan. Throughout the experiments all presentations of the tone, light, and noise stimuli were 30 seconds in duration. A dipper cup could deliver a .1 ml drop

of water to the water well. The floor bars were connected, by circuit described by Bintz (1970), to a shock source that delivered .5 sec, .5 ma shocks. Experimental events were controlled and recorded by solid state programming equipment in an adjacent room.

C. Procedure

Lever Press Training

Five days after the deprivation schedule began, lever press training was given. Each subject was placed in a conditioning chamber and received 30 drops of water on a variable time 1 minute schedule. In addition, each lever press produced a drop of water. Each subject was allowed 75 presses and was then returned to its home cage. After the initial lever press training session, all sessions lasted 90 minutes. Subjects were placed in the chambers and lever pressed on a variable interval 1 minute schedule for water reinforcement. During the next five sessions, no events other than water reinforcement were presented. This phase allowed for a firm baseline rate of pressing to become established.

CS1 Pretest

In the next two sessions the tone and light stimuli were presented. During each of these sessions, two tones and two lights were individually superimposed on the lever pressing baseline. Throughout the experiment, stimulus presentation trials were spaced according to a variable time schedule. Whenever more than one type of trial occurred within a single session, the trials were randomly ordered. After tone and light pretesting was completed, five groups of eight subjects each were matched on the amount of unconditioned suppression to the tone and light.

First-Order Conditioning

On each of four days of first-order conditioning all groups received presentations of the light, tone, and shock. Table I summarizes the procedure for this and all stages of the experiment. In first-order conditioning, groups received tones and lights either individually (symbolized in their group names by a leading "I") or in a simultaneous compound (symbolized by a leading "C"). Two groups, I-I and I-C, received two 30 sec lights and two 30 sec tones followed by shocks in a zero second trace procedure. Two other groups, C-C and G, received four 30 sec tone-light compounds each followed by shock. Thus, four groups received four CS-US pairings in each of four days of first-order conditioning. In addition, Group R received four tone-light compounds

explicitly unpaired with four shocks per day. After first-order conditioning was completed, one day of lever pressing was given to allow recovery of lever pressing rates. On this day, no stimuli other than the water rewards were presented.

CS2 Pretest

In the next session, four 30 sec presentations of the noise were given. This pretest of the noise was intended to disclose whether there was any differential generalization to the noise from the various first-order conditioning procedures, as well as to provide an assessment of unconditioned responding to the noise.

Second-Order Conditioning

In each of the three second-order conditioning sessions Groups I-C, C-C, and R received noise presentations followed by presentations of the tone-light compound. Group I-I received noise presentations followed by individual tones or lights; four subjects received lights and four received tones. Group G received tone-light compounds and noises in an explicitly unpaired fashion.

CS1 Extinction

For all groups the tone-light compound was extinguished first, then the elements were extinguished individually. On each of five days of compound extinction, six presentations of the compound were given to all groups. The element extinction included three sessions, each session consisting of three tone and three light presentations.

CS2 Test

After extinction, a single session was devoted to reassessing responding to the noise stimulus. All groups were given four presentations of the noise.

D. Measures and Analyses

The measure of conditioning was the amount of suppression of lever pressing produced by stimulus presentations. For each subject, suppression was measured by the ratio A/(A+B), where A was the rate of responding during the CS and B was the rate of responding during a 4 minute period prior to CS onset. A suppression ratio of 0 indicates complete cessation of lever pressing during the CS (good conditioning), while one of .5 indicates no change in the rate during the CS (poor conditioning).

The following procedure was used in each planned statistical analysis. Any overall group difference was first tested by a Kruskal-Wallis one-way analysis of variance. If an overall group difference was obtained, individual pairwise comparisons, using the Mann-Whitney $\underline{U}$ statistic, were performed to draw inferences concerning specific group differences. This procedure resulted in a per comparison error rate. Since specific hypothesized group differences were being tested, all probability values are one-tailed unless otherwise specified.

III. Results

First-Order Conditioning

First-order conditioning treatments involved two types of tone and light presentations: compound and individual. Groups I-I and I-C received individual tones and lights during first-order conditioning. Figure 1 represents suppression observed during the tone and Figure 2 represents suppression during the light for these two groups. By the second block of two trials, mean suppression ratios to both tone and light were below .1 in both groups. Figure 3 shows the effect of the first-order conditioning manipulations upon suppression in groups presented the tone-light compound. Groups C-C and G, which received the compound paired with shock, had mean suppression ratios below .1 on the second block of trials and maintained this level of suppression over the course of first-order conditioning. Thus, the rate of first-order conditioning with element CSs (Groups I-I and I-C), was found to be very similar to that observed when the compound CS was used (Groups C-C and G). For Group R, the first-order conditioning control, the tone-light compound did not come to produce a comparable degree of suppression: mean ratios for this group never dipped below .4.

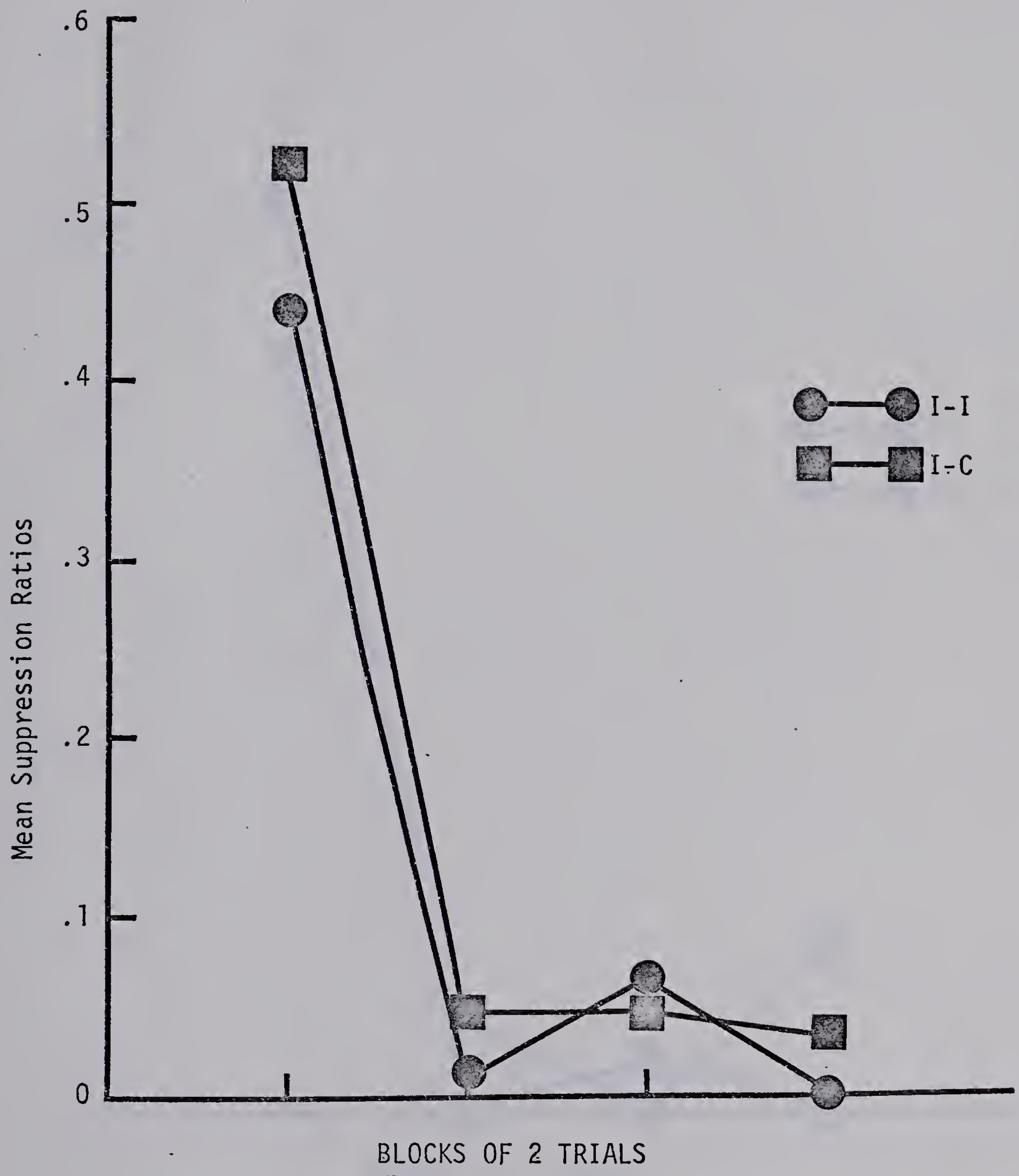

Figure 1.

Mean suppression ratios for Groups I-I and I-C during first-order conditioning of the tone stimulus.

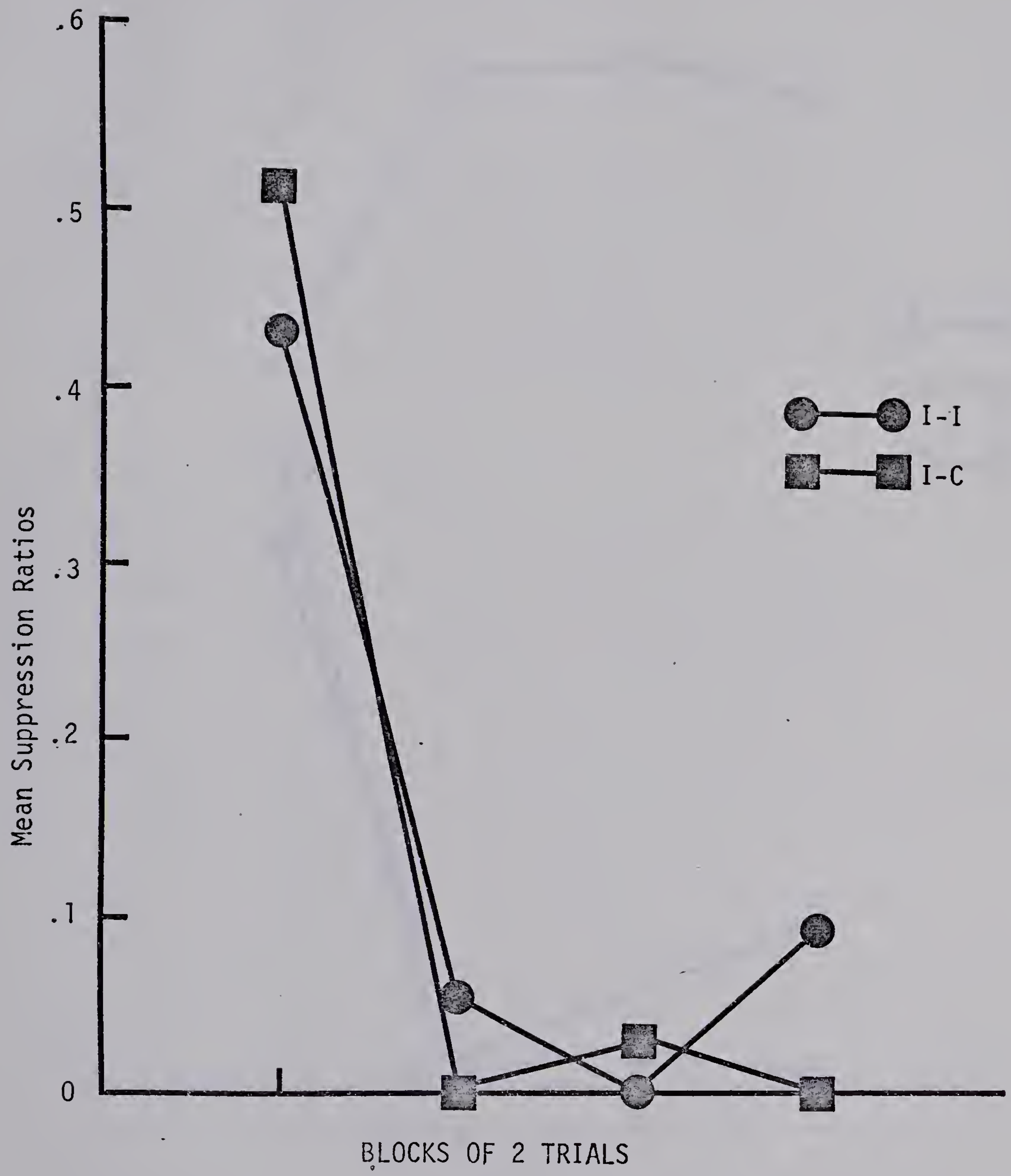

Figure 2.

Mean suppression ratios for Groups I-I and I-C during first-order conditioning of the light stimulus.

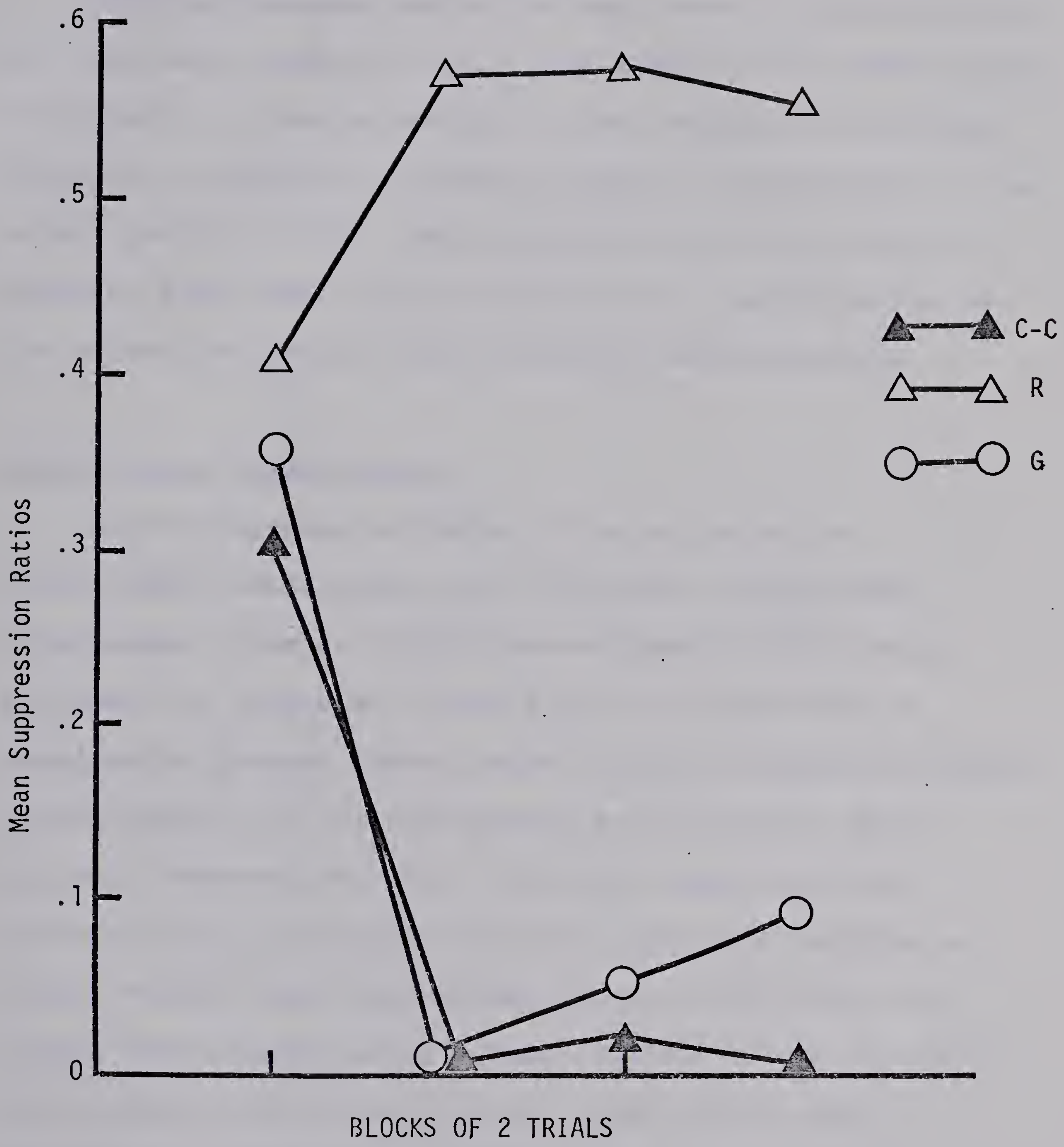

Figure 3.

Mean suppression ratios for Groups C-C, R, and G during the first eight trials of first-order conditioning of the tone-light compound stimulus.

CS2 Pretest

Mean suppression ratios for each group, collapsed over the four noise pretest trials, are shown in the left portion of Figure 4. A Kruskal-Wallis one-way analysis of variance detected no difference between groups in suppression to the noise ($\underline{H}=6.45$, $p>.10$). This homogeneity can be taken as evidence that there was no differential generalization to the noise from any of the first-order manipulations.

Second-Order Conditioning

Since subgroups of Group I-I were trained in second-order conditioning with different second-order reinforcers (tone or light), Mann-Whitney $\underline{U}$ tests were performed to determine if there was any difference in suppression between these groups on any of the second-order conditioning days: no differences were detected ($\underline{U}s>3$, $ps>.10$). Therefore the data for these subgroups were combined into the single Group I-I. The right portion of Figure 4 shows mean suppression ratios to the noise on second-order conditioning trials, collapsed over blocks of four trials. Since data from the first second-order conditioning trial do not reflect second-order conditioning, the first block consists only of trials two through four. Although no differences in responding to the noise pretest were observed, differences in responding to the noise during second-order conditioning were apparent. On the third day of second-order conditioning, a Kruskal-Wallis test indicated

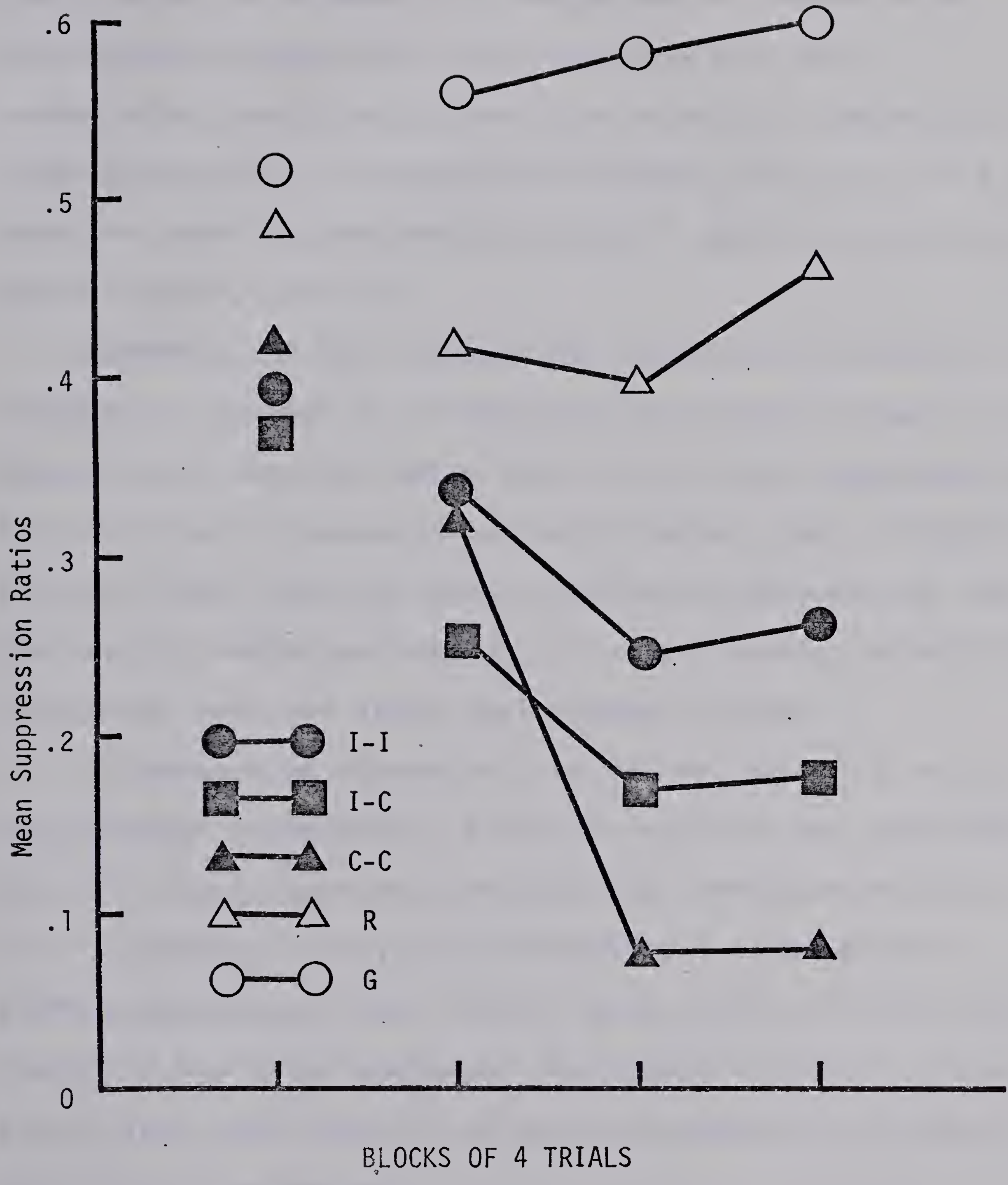

Figure 4.

Mean suppression ratios for all groups to the white noise stimulus during pretesting (at left) and during second-order conditioning.

an overall group difference (*H*=28.6, $p<.001$). Second-order conditioning is evident by a comparison of second-order conditioning groups (I-I, I-C, and C-C) with the second-order conditioning controls (R and G). Individual Mann-Whitney tests indicated that Groups I-I, I-C, and C-C were each more suppressed than Group R (*U*s<12, ps<.02) and Group G (*U*s<1, ps<.001).

Summation of the second-order reinforcing power of CS1 elements is evident by a comparison of Groups I-I and I-C. A Mann-Whitney test indicated that I-C was more suppressed on the third day of second-order conditioning than I-I (*U*=16, p=.052). This indicates that a compound consisting of two previously conditioned stimuli is a more potent second-order reinforcer than the individual elements alone.

Inspection of Groups I-C and C-C on the third day of second-order conditioning failed to support the prediction that I-C should show more second-order conditioning than C-C. Statistical analysis confirmed that there was no difference between these groups (*U*=48, p>.4). In addition, Group C-C was more suppressed than Group I-I (*U*=10, p<.02 two-tailed), and Group R was more suppressed than Group G (*U*=1, p<.01 two-tailed).

CS1 Extinction

Figure 5 represents suppression to the tone-light compound during extinction. Groups I-C, C-C, and G showed similar decreases in suppression to the compound as a function of extinction trials. Group I-I showed a much slower rate of extinction. Ideally, all groups would have shown similar amounts of suppression to the compound as a result of extinction trials. Practical considerations argued against continuing extinction of the compound to attain this ideal. First, the data of interest, seemingly uncontaminated by differences in generalization from CS1 to CS2, had been obtained previously during second-order conditioning. Second, it appeared that several additional days of extinction would be required in order that Group I-I show suppression comparable to that of other groups. This would have delayed the testing of the noise CS2 by a period of time which might have severely attenuated retention of suppression to the noise. Since the purpose of CS1 extinction was to remove any possible difference in generalization between Groups I-C and C-C, and no difference was apparent on the final day of compound extinction ($\underline{U}=23$, $p=.191$), no further extinction of the compound was given.

Figures 6 and 7 represent suppression during extinction of individual tones and lights respectively. By the third day of element extinction suppression to the tone had reached a similar level in all groups, but Group I-I

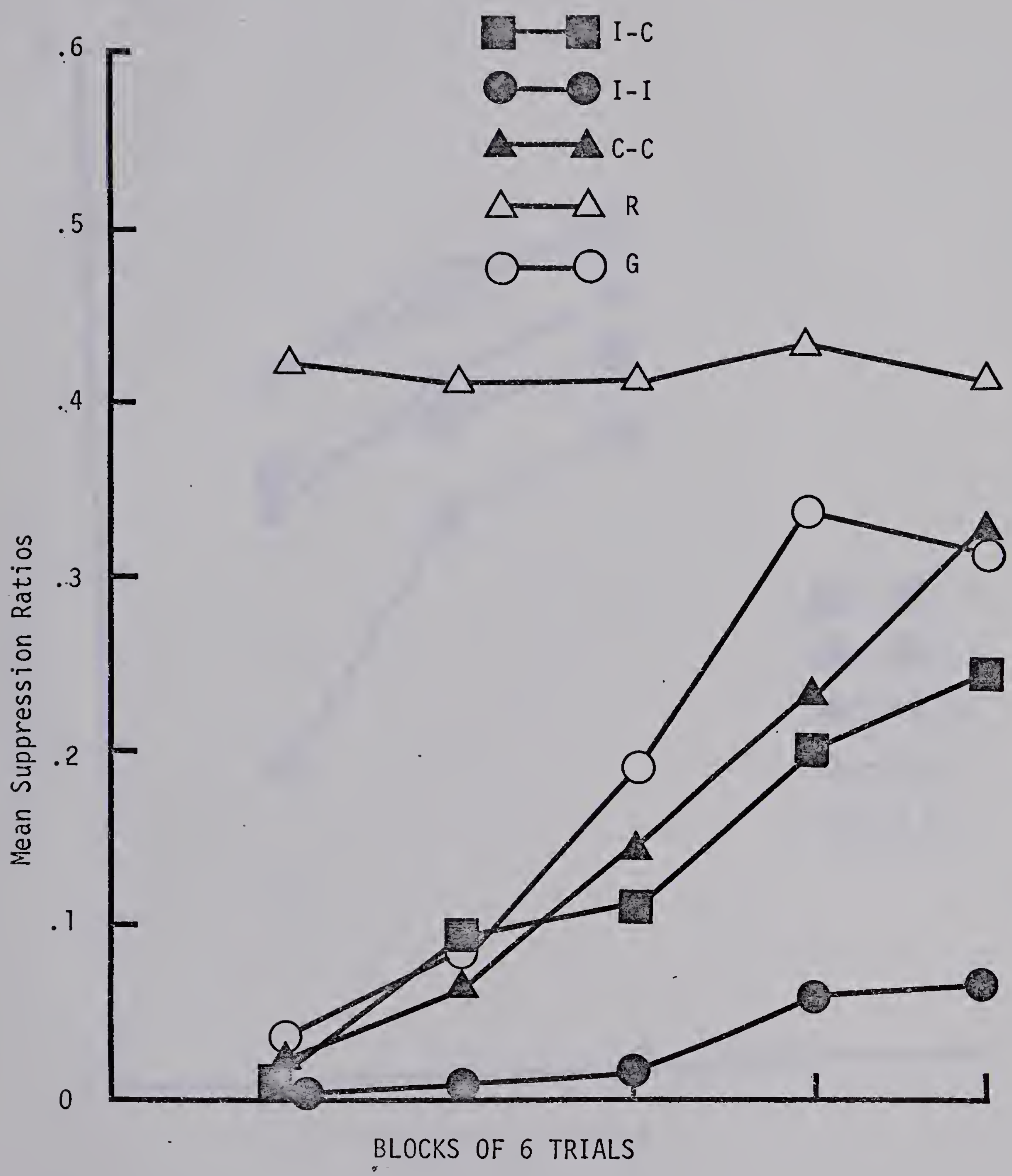

Figure 5.

Mean suppression ratios for all groups during extinction of the tone-light compound stimulus.

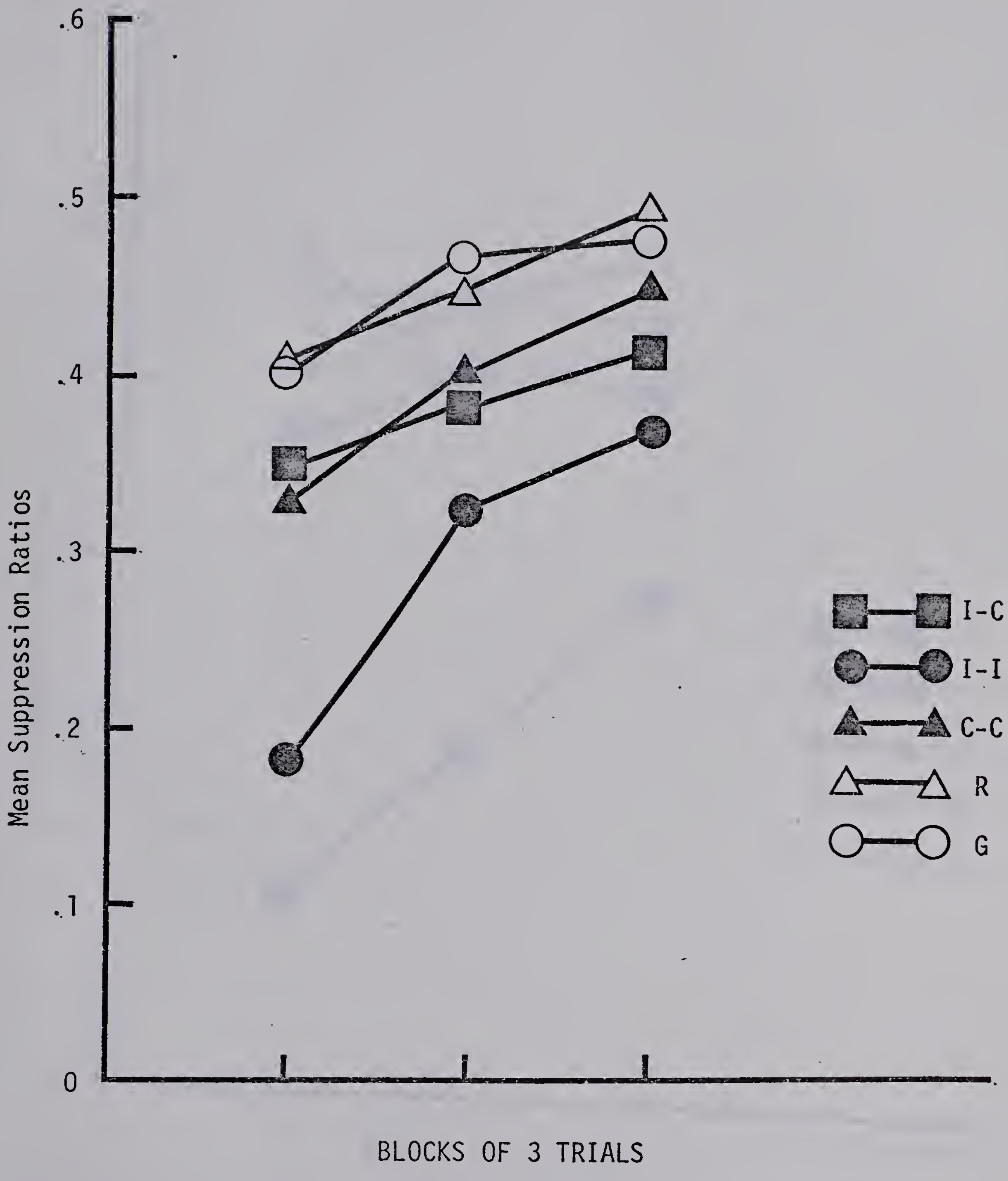

Figure 6.

Mean suppression ratios for all groups during extinction of the tone stimulus.

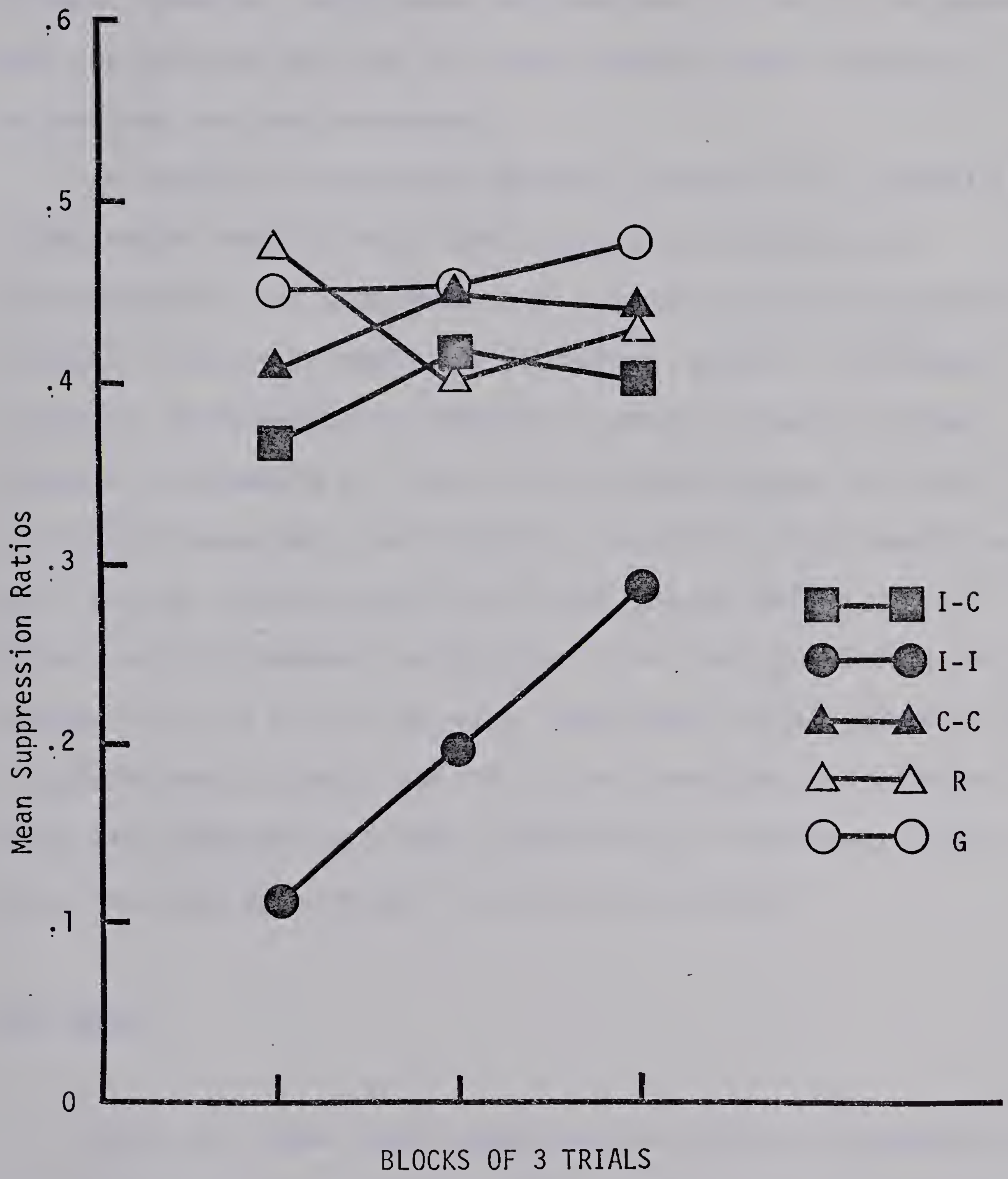

Figure 7.

Mean suppression ratios for all groups during extinction of the light stimulus.

remained notably more suppressed to the light than did other groups. However, additional extinction of the CS1 elements was not carried out for the same reasons that compound extinction was not extended.

In order to determine whether training CS1 elements in first-order conditioning led to greater conditioned responding to the compound than training the CS1 compound itself, a post-hoc contrast procedure using a confidence interval (Marascuilo & McSweeney, 1967) compared groups receiving elements in first-order conditioning (I-I and I-C) to groups receiving the compound in first-order conditioning (C-C and G). Using data from these groups (df=3) on the final day of compound extinction, the contrast indicates Groups I-C and I-I to be more suppressed than Groups C-C and G ($p<.05$ two-tailed). The CR to the compound was greater when its elements had been individually conditioned than when the compound itself had been conditioned.

<u>CS2 Test</u>

Table II gives mean suppresssion ratios collapsed over the four test presentations of the noise for each group. An overall group difference on these data was indicated by the Kruskal-Wallis statistic ($\underline{H}=16.12$, $p<.01$). Individual Mann-Whitney tests showed that second-order conditioning persisted into this stage. All second-order conditioning groups (I-C, I-I, and C-C) differed from both of the

Group	Mean Suppression Ratio
I-C	.377
I-I	.438
C-C	.369
G	.609
R	.543

Table II.

Mean suppression ratios for each group during testing of the white noise stimulus.

second-order conditioning controls, Group R (*U*s<16, ps<.05) and Group G (*U*s<8, ps<.005). However, no other differences could be observed after extinction of the CS1s; Group I-C was no longer more suppressed to the noise than Group I-I (*U*=20, p=.117), nor was Group C-C more suppressed than Group I-I (*U*=25, p=.253).

IV. Discussion

The results of the experiment satisfy two of the purposes stated in the introduction. First, there was a convincing demonstration of substantial second-order conditioning. This assures that responding to CS2 in all three second-order conditioning groups does indeed represent second-order conditioning relative to reinforcement and generalization controls. Second, Holland's (1977) finding that a compound consisting of previously reinforced CS1 elements served as a more powerful second-order reinforcer than either of the elements alone, has been replicated and extended to an aversive conditioning situation. Thus, summation of the second-order reinforcing power of CS1 elements has now been demonstrated using both appetitive and aversive USs.

The results bearing on the third purpose were less conclusive. Recall that this purpose was to test the hypothesis that Group I-C would show greater second-order conditioned responding than Group C-C. The rationale behind this hypothesis can be divided into three parts. First, the CR to the compound CS1 was expected to be affected by differences in first-order conditioning procedures. First-order conditioning with elements CS1s was supposed to lead to greater conditioned responding to the compound than first-order conditioning with the compound CS1 itself. Second, it was assumed that the difference in conditioned

responding to the compound would occur during its presentation on second-order conditioning trials. Third, the difference in the CR to the compound CS1 during second-order trials was hypothesized to result in a concommitant difference in second-order conditioned responding. The failure of Group I-C to show greater second-order conditioned responding than Group C-C may reflect a failure of any component of the rationale. Accordingly, three general alternate hypotheses are offered to account for the failure to observe greater second-order conditioned responding in Group I-C than in Group C-C.

1. The first-order manipulations designed to affect the strength of the CR to the compound may not have had the intended effect.
2. Differences in conditioned responding to CS1 or CS2 may have been mitigated during second-order trials.
3. The establishment of second-order conditioned responding depends upon something other than, or in addition to, the CR elicited by CS1.

Consider the hypothesis that the first-order manipulations may not have been effective in producing differences in the CR to the compound. If the manipulations were effective, that is, if element training did lead to greater conditioned suppression than training of the compound itself, a difference in responding to the CS1 compound might have been observed during second-order conditioning, or during extinction of the compound. Because

the original hypothesis held that the CR-eliciting strength of CS1 during second-order conditioning determines the strength of conditioning to CS2, the CR would have ideally been assessed during second-order conditioning. Unfortuanately, any potential difference in suppression to the compound during second-order conditioning was obscured by a dramatic floor effect. However, the CR was assessed during extinction trials, where the post-hoc contrast focusing on individual versus compound training did show element training to result in greater CRs to the compound.

Thus, element CS1 training did produce greater conditioned responding to the CS1 compound as measured during extinction. However, the second alternate hypothesis proposes that this effect may have been mitigated for Group I-C relative to C-C during the course of second-order trials. It is plausible that factors related to the strength of conditioned responding to CS1 could have attenuated potential differences in second-order conditioned responding. Two ways in which this might have occurred will be considered. The first can best be understood by comparing the standard second-order conditioning procedure to that for establishing conditioned inhibition. It has long been recognized that the conditioned inhibition procedure bears a strong resemblance to that of second-order conditioning (Herendeen & Anderson, 1968; Pavlov, 1927; Rescorla, 1973). In the conditioned inhibition procedure, a single element CS, A, is paired with a US. Subsequent presentations of a

compound CS, AX, occur in the absence of the US. As a result, stimulus X becomes a conditioned inhibitor; it becomes able to inhibit the CR. In establishing second-order conditioning, CS1 is followed by the US during first-order conditioning trials, then, during second-order conditioning trials the sequential CS2-CS1 compound occurs in the absence of the US. It has been shown that CS2, similarly to stimulus X in the conditioned inhibition procedure, does in fact acquire inhibitory properties as a result of prolonged second-order conditioning (Herendeen & Anderson, 1968; Holland & Rescorla, 1975). In the present study it is possible that inhibitory properties might have accrued to CS2, mitigating second-order conditioned responding in Groups I-C and C-C. Moreover, it is plausible that Group I-C developed more inhibition to CS2. It has been demonstrated by Wagner, Saavedra, and Lehman (Wagner, 1969) and by Wagner & Saavedra (Wagner, 1971) that the stronger the CR elicited by stimulus A, the greater was the amount of inhibition that accrued to stimulus X. Similarly, Group I-C may have developed more inhibition to CS2 than did Group C-C. Such a difference in inhibition could have nullified any potential difference in second-order conditioned responding between Groups I-C and C-C. A second way in which the difference between Groups I-C and C-C may have been mitigated involves the possibility that there were different rates of extinction to CS1 during second-order trials. Recall that Group I-C received element CS1s during first-order trials

and compound CS1s during second-order trials. This change from reinforced elements to nonreinforced compounds closely resembles the conditioned inhibition procedure. Consequently, it is plausible that during second-order trials the CS1 compound lost its ability to elicit a CR to a greater extent for Group I-C than for Group C-C. Although these mitigation hypotheses seem to account for the failure to find a difference in second-order conditioned responding between Groups I-C and C-C, they are not without problems. Both explanations imply that the difference between Groups I-C and I-I should also have been nullified, or at least attenuated. However, this difference was in fact obtained. It is possible that the difference between I-C and I-I was greater than that between I-C and C-C, so that in the former case a residual strength remained while in the latter case the difference was depleted.

The third and final alternative is that a property of CS1, other than the CR it elicits, affected second-order conditioned responding. As mentioned in the introduction, physical properties of CS1 may affect the amount of second-order conditioning which CS1 can support (Zimmer-Hart, note 1). Results of the present study might be interpreted as suggesting that one important physical property of CS1, in the present investigation, was the number of elements it contained. It is clear, since Group I-I showed greater second-order conditioned responding than did Group R, that receiving compound CS1s during the

second-order phase did not invariably lead to greater suppression. However, differences in this physical property do explain some aspects of the data. The fact that Groups I-C and C-C did not differ in conditioned responding to CS2, yet did differ from Group I-I, may reflect that Groups I-C and C-C were trained with compound CS1s during second-order conditioning while Group I-I received element CS1s. Also consistent with this hypothesis is the result that Group C-C showed greater second-order conditioning than did Group I-I. One implication of these results is that nominal second-order conditioning may actually reflect more than one theoretically distinct learning process.

Reference Note

1. Zimmer-Hart, C. L. The discrepancy principle in Pavlovian second-order conditioning. Unpublished manuscript, 1974.

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